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Sea Ice Sensitivities in the 0.72°and 0.08° Arctic Cap Coupled HYCOM/CICE Models

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LONG-TERM GOALS

Perennial Arctic ice extent, which corresponds to the sea ice that remains during the summer minimum, has decreased over the years 1979–2007 by more than 10% per decade (Comiso et al., 2008). The decline has been faster over recent years, leading to very low ice concentration in the summers of 2007 and 2008 (Goosse et al. 2009) with the lowest observed sea ice extent in the satellite record (1979-present) occurring in September 2012 (Perovich et al. 2012). Further reduction in perennial ice extent will likely lead to the inception of new shipping lanes through the Arctic bringing both opportunities for commerce and the need for heightened defense scrutiny. Prediction of future Arctic sea ice conditions, on both short and longer-term time scales are dependent on the capability of the component models in integrated Arctic and global models. The long-term goal of this project, therefore, is to improve the performance of the sea-ice model used in the Navy's coupled ocean and sea-ice prediction systems. These models consist of the Hybrid Coordinate Ocean Model (HYCOM) and the Los Alamos National Laboratory (LANL) CICE model.

OBJECTIVES

The objectives of the project are to optimize the depiction of ice processes in existing Navy Research Laboratory (NRL) configurations of coupled HYCOM/CICE using sensitivity testing, and together with NRL implement and test new versions of CICE in these coupled model set-ups as they become available from the LANL developers.

APPROACH

To optimize the depiction of ice processes in existing configurations of coupled HYCOM/CICE, sensitivity testing of sea-ice is taking place using the computationally inexpensive low-resolution 3/4° global HYCOM/CICE setup known as GLBt0.72. The model was initialized from GDEM4 and 3-m ice and was run for five years using climatological atmospheric forcing. It was then forced with 3-hourly Navy Operational Global Atmospheric Prediction System (NOGAPS) forcing for the years 2003-2012, with modifications to the ingestion of surface winds starting in 2009. Our tests will explore sensitivities to atmospheric forcing, the choice of the parameterization of shortwave radiation transfer in ice and snow, and ice parameter tuning. The ice fields will be compared with independent ice

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observations such as ICESat ice thicknesses and ice drift speeds from ice buoy data. Once we understand the impact of these changes on the simulated ice, we will identify the optimal ice set-up and conduct a 1/12° Arctic Cap (ARCc0.08) simulation for the 2000s. Upgrades to CICE will be tested using this same approach as they become available from the CICE developers.

WORK COMPLETED

This project started in spring of 2013 and since that time we have begun our sensitivity testing using the low resolution model. NRL provided the GLBt0.72 code and some time was spent iterating with them to understand the scripting of the coupled model code which uses the Earth System Model Framework. We have successfully run it for 2009 starting from a spun-up ocean/sea-ice state representative of the end of 2008 that was obtained through the methodology discribed in the previous section. We are now examining the baseline veracity of the simulation by comparing it with sea ice and ocean observations.

We have ported the Community Earth System Model (CESM) ice diagnostics code to Kilrain, an IBM iDataPlex System at the Navy DoD Supercomputing Resource Center (Navy DSRC) where GLBt0.72 is being run. We are in the midst of modifying scripts to ingest the GLBt0.72 output into the diagnostics package. Once the code is working we will routinely use it to monitor model progress during runs. The package produces fields of ice thickness and concentration, basal and top ice melt, ice volume and area ice tendencies, among other variables. As well, we are now setting up GLBt0.72 to run the senstivity tests described above for 2003-2012. Finally we are participating in weekly telephone conference calls among the National Center for Atmospheric Research, the University of Florida, and NRL scientists who are funded to incoporate HYCOM into CESM. They will share their prototype with us for testing purposes once it becomes available.

RESULTS

Our initial results from the low resolution global HYCOM/CICE simulation focus on the depiction of the ocean/sea-ice interface. In Fig.1 we show monthly averaged sea ice concentration for March (left) and September (right) of 2009 from HYCOM/CICE (upper panel), Special Sensor Microwave/Imager (SSM/I) (middle panel), and their difference (lower panel). In both months the simulated ice edge location is closely co-located with that of observations. In September the model overestimates ice concentrations in much of the central Arctic, with values greater than 50-70% in places. Note that the the models are not assimilating any data. Sea surface temperature (SST) for March (left) and September (right) of 2009 from HYCOM/CICE is seen in Fig. 2 (upper panel) with the 15% model sea ice concentration contour overlaid. The middle panel shows the equivalent fields from observations: Hadley Center Sea Ice and Sea Surface Temperature data set (HadISST) and SSM/I while the lower panel shows the difference between the simulated and observed SSTs. In March little or no model bias is seen in SST while in September warm biases (~3-4°C) occur in the model in the Greenland-Icelandic-Norwegian (GIN) seas and the Davis Strait with the highest values occurring where the ice edge is slightly misplaced relative to observations.

Comparisons of available ice thickness onbservations from ICESat for 2004-2008 (Kwok and Rothrock, 2009) for February-March and October-November with model fields from 2009 for each of these two months indicate that the simulated ice is too thick in the Beaufort Sea and too thin in the the eastern Arctic. Regardless of the mismatch in years being compared, these biases are unlikely to be due

to year-to-year variability. Understanding the causes of these biases and improving the representation of the model ice thickness in HYCOM/CICE is the basis of our ongoing sensitivity studies.

IMPACT/APPLICATIONS

Improved realism of sea-ice in the Navy's operational coupled ocean/sea-ice prediction system should reduce uncertainty in predictions and provide increased confidence in projections for decision making.

REFERENCES

Comiso, J. C., C. L. Parkinson, R. Gersten, and L. Stock, 2008: Accelerated decline in the Arctic sea ice cover, *Geophys. Res. Lett*., 35, L01703, doi:10.1029/2007GL031972.

Goosse, H., O. Arzel, C. M. Bitz, A. de Montety, and M. Vancoppenolle, 2009: Increased variability of the Arctic summer ice extent in a warmer climate, *Geophys. Res. Lett*., 36, L23702, doi:10.1029/2009GL040546.

Kwok, R., and D. A. Rothrock, 2009, Decline in Arctic sea ice thickness from submarine and ICESat records: 1958-2008, *Geophys. Res. Lett*., 36, L15501,doi:10.1029/2009GL039035.

Perovich, D., W. Meier, M. Tschudi, S. Gerland, and J. Richter-Menge, 2012: Sea ice and ocean [in Arctic Report Card 2012], http://www.arctic.noaa.gov/reportcard

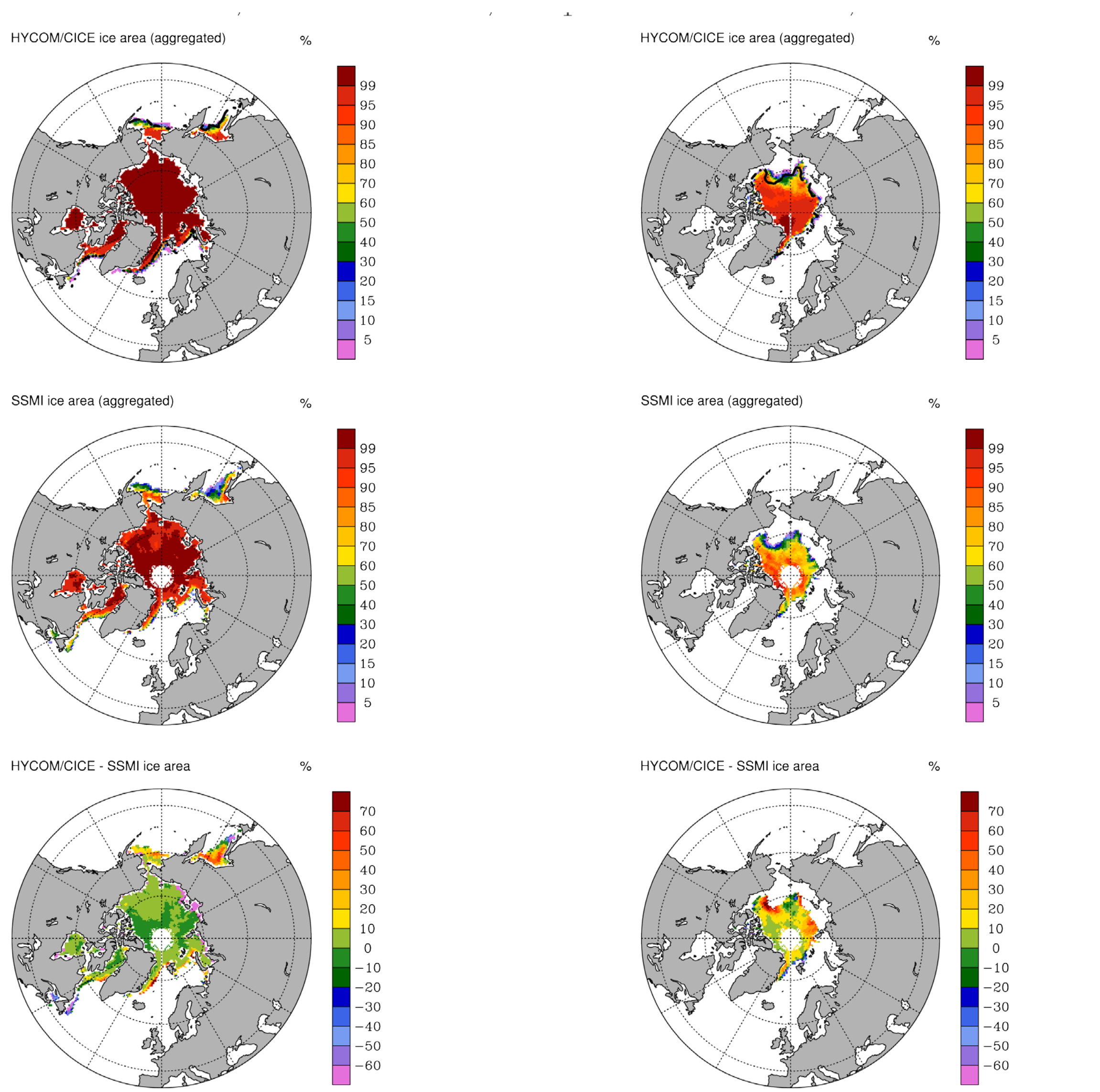

Figure 1. Monthly-averaged sea ice concentration for March (left) and September (right) of 2009 from global 3/4° HYCOM/CICE (upper panel), Special Sensor Microwave/Imager (SSM/I) (middle panel), and their difference (lower panel).

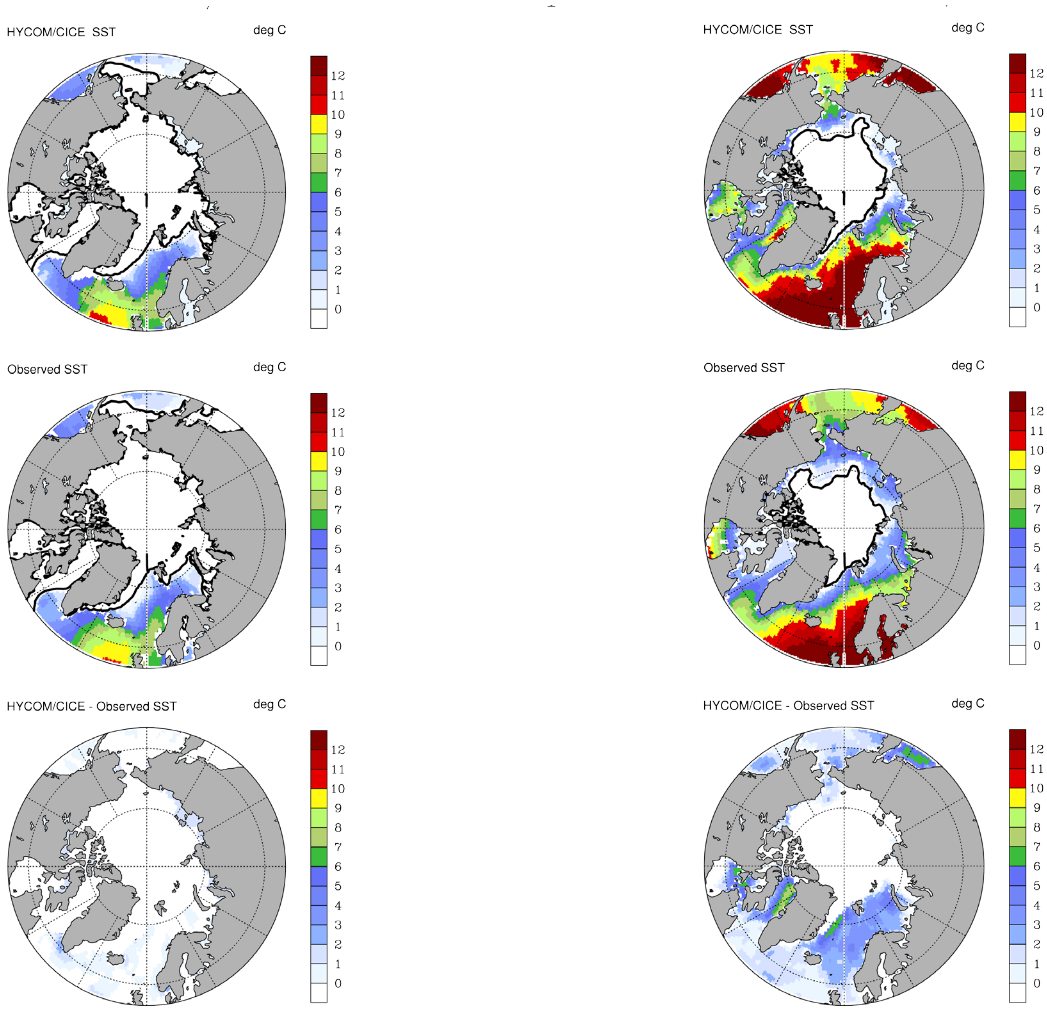

Figure 2: Sea surface temperature (SST) for March (left) and September (right) of 2009 from HYCOM/CICE (upper panel) with the 15% model sea ice concentration contour overlaid. The middle panel shows the equivalent fields from observations: Hadley Center Sea Ice and Sea Surface Temperature data set (HadISST) and SSM/I while the lower panel shows the difference between the simulated and observed SSTs.